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RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Department of the Navy

FREE-SPINNING-TUNNEL INVESTIGATION OF A $\frac{1}{30}$-SCALE MODEL OF THE GRUMMAN XS2F-1 AIRPLANE

TED NO. NACA DE 366

By Frederick M. Healy

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Langley Field, Va.

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON

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SUMMARY

An investigation of a $\frac{1}{30}$- scale model of the Grumman XS2F-1 airplane has been conducted in the Langley 20-foot free-spinning tunnel. The erect spin and recovery characteristics of the model in the design flight condition with the center of gravity at 30 percent of the mean aerodynamic chord were determined. Brief tests were also performed with the center of gravity at 20 percent of the mean aerodynamic chord. The effect of reversing the trimmer simultaneously with the rudder and the effect of extending the radome and magnetic airborne detector boom were also determined. The investigation included inverted spin tests and tests to determine the parachute size required for emergency spin recovery.

The results of the tests indicate that erect spins of the airplane with flaps retracted when the center of gravity is at 30 percent of the mean aerodynamic chord will be satisfactorily terminated by full rudder reversal accompanied by moving the elevator to at least two-thirds down. Recoveries attempted by simultaneous reversal of rudder and trimmer will be satisfactory. Full rudder reversal and elevator neutralization will give satisfactory recovery when the center of gravity is at 20 percent of the mean aerodynamic chord. Extension of the radome and boom will have little effect on spin-recovery characteristics. Inverted spins of the airplane will be satisfactorily terminated by full rudder reversal. The model tests indicate that an 18.75-foot (laid-out-flat diameter) tail parachute (drag coefficient approximately 0.74) should be effective as an emergency spin-recovery device during demonstration spins of the airplane.

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INTRODUCTION

At the request of the Bureau of Aeronautics, Department of the Navy, a spin investigation has been conducted in the Langley 20-foot free-spinning tunnel of a $\frac{1}{30}$-scale model of the Grumman XS2F-1 airplane. The XS2F-1 is a high-wing, twin-engine aircraft of conventional configuration. The airplane is equipped with a retractable ventrally located radome and a magnetic airborne detector boom which retracts into the tail cone.

The erect and inverted spin and recovery characteristics of the XS2F-1 model in the most rearward (0.30 mean aerodynamic chord) center-of-gravity loading condition were determined. Brief tests were also performed with the model in the most forward (0.20 mean aerodynamic chord) center-of-gravity condition. The effects of horizontal-stabilizer incidence settings of both 0° and -6° were investigated. Tests were made by simulating both the retracted and extended positions of the radome and magnetic airborne detector boom. The investigation also included parachute-recovery tests.

SYMBOLS

b	wing span, ft
S	wing area, sq ft
c	wing chord at any station along the span, ft
$\bar{c}$	mean aerodynamic chord, ft
$x/\bar{c}$	ratio of distance of center of gravity rearward of leading edge of mean aerodynamic chord to mean aerodynamic chord
$z/\bar{c}$	ratio of distance between center of gravity and fuselage reference line to mean aerodynamic chord (positive when center of gravity is below line)
m	mass of airplane, slugs
I_X, I_Y, I_Z	moment of inertia about X-, Y-, and Z-body axes, respectively, slug-ft^2

$\frac{I_X - I_Y}{mb^2}$ inertia yawing-moment parameter

$\frac{I_Y - I_Z}{mb^2}$ inertia rolling-moment parameter

$\frac{I_Z - I_X}{mb^2}$ inertia pitching-moment parameter

ρ air density, slug/cu ft

μ relative density of airplane, $m/\rho Sb$

α angle between fuselage reference line and vertical (approximately equal to absolute value of angle of attack at plane of symmetry), deg

ϕ angle between span axis and horizontal, deg

V full-scale true rate of descent, ft/sec

Ω full-scale angular velocity about spin axis, rps

TDPF tail-damping power factor (ref. 1)

APPARATUS AND METHODS

Model

The $\frac{1}{30}$-scale model of the Grumman XS2F-1 airplane used for the tests was furnished by the Bureau of Aeronautics and was prepared for testing by the Langley Laboratory of the National Advisory Committee for Aeronautics. A three-view drawing of the model as tested is shown in figure 1. Photographs of the model are shown in figures 2 and 3. The dimensional characteristics of the airplane are presented in table I.

The model was ballasted with lead weights to obtain dynamic similarity to the airplane at an altitude of 30,000 feet (ρ = 0.000889 slug/cu ft) rather than the usual 15,000 feet. This ballasting was necessary because of the relatively heavy construction of the model. A remote-control mechanism was installed in the model to actuate the controls for the recovery attempts. Sufficient hinge moments were exerted on the controls for the recovery attempts to reverse them fully and rapidly.

The control system of the XS2F-1 includes a movable surface, known as a trimmer, located in the position normally occupied by the rudder. The rudder is hinged to the trailing edge of the trimmer. In an emergency (single-engine) condition, the trimmer deflects proportionally to the rudder. In normal flight, this surface is manually operated. On the model, the trimmer was preset at certain fixed conditions or deflected simultaneously with the rudder.

Conventional flap-type ailerons and circular-arc spoilers are used for lateral control of the XS2F-1. The spoilers are located inboard of the ailerons and deflect above the upper surface of the wing. (See figs. 1 and 3.)

A removable radome and magnetic airborne detector boom were used on the model to represent the radome- and boom-extended configuration.

Wind Tunnel and Testing Technique

The model tests were performed in the Langley 20-foot free-spinning tunnel, the operation of which is generally similar to that described in reference 2 for the Langley 15-foot free-spinning tunnel except that the model launching technique has been changed. With the controls set in the desired position, the model is launched by hand with rotation into the vertically rising air stream. After a number of turns in the established spin, the recovery attempt is made by moving one or more controls by means of the remote-control mechanism. After recovery, the model dives into a safety net. The spin data obtained from these tests are then converted to corresponding full-scale values by methods also described in reference 2. A photograph of the model during a spin is shown in figure 4.

Spin-tunnel tests are usually performed to determine the spin and recovery characteristics of the model for the normal spinning-control configuration (elevator full up, lateral controls neutral, and rudder full with the spin) and for various other lateral-control-elevator combinations including neutral and maximum settings of the surfaces for various model loadings and configurations. Recovery is generally attempted by either rapid full rudder reversal or rapid full reversal of both rudder and elevator. For certain spins of the present model recovery was also attempted by rapid full reversal of rudder and trimmer. Tests are also performed to evaluate the possible adverse effects on recovery of small deviations from the normal control configuration for spinning. For these tests, the elevator is set at either full up or two-thirds of its full-up deflection and the lateral controls are set at one-third of full deflection in the direction conducive to slower recoveries (with the spin, wheel right in a right spin, for the

XS2F-1 model). Recovery from this spin is attempted by rapidly reversing the rudder from full with to only two-thirds against the spin or by simultaneous rudder reversal to two-thirds against the spin and movement of the elevator to either neutral or two-thirds down. For the spins in which rudder and trimmer were simultaneously deflected, recovery was attempted by rapidly reversing both rudder and trimmer to two-thirds against the spin. These control configurations and manipulations are referred to as the "criterion spin."

Turns for recovery are measured from the time the controls are moved, or the parachute opened, to the time the spin rotation ceases. Based on experience with many models, the criterion for a satisfactory recovery from a spin for the model has been adopted as $2\frac{1}{4}$ turns or less. Recovery characteristics indicated by the model may be considered satisfactory if recovery attempted from the criterion spin in the manner previously described is accomplished within $2\frac{1}{4}$ turns.

For the spins which had a rate of descent in excess of that which can readily be obtained in the tunnel, the rate of descent was recorded as greater than the velocity at the time the model hit the safety net, for example, >365 feet per second, full scale. For these tests, the recovery was attempted before the model reached its final steeper attitude and while the model was still descending in the tunnel. Such results are considered conservative, that is, recoveries will not be as fast as when the model is in the final steeper attitude. For recovery attempts in which the model struck the safety net while it was still in a spin, the recovery was recorded as greater than the number of turns from the time the controls were moved to the time the model struck the safety net, as >3. A >3-turn recovery, however, does not necessarily indicate an improvement over a >7-turn recovery. When the model recovered without control movement (rudder with the spin), the results were recorded as "no spin."

For the spin-recovery parachute tests, the minimum-size tail parachute required to effect recovery within $2\frac{1}{4}$ turns from the criterion spin was considered satisfactory. The parachute was opened for the recovery attempts by actuating the remote-control mechanism and the rudder was held with the spin so that recovery was due to the parachute action alone. The parachute towline was attached to the fuselage at the bottom of the tail cone. The folded spin-recovery parachute was placed on the model in such a position that it did not seriously influence the established spin. For the model tests, a rubber band holding the packed parachute to the model was released and the parachute was blown free of the model. On the full-scale parachute installation it would be desirable to mount the pack within the airplane structure, if possible, and it is recommended that a mechanism be employed for positive ejection of the parachute.

PRECISION

The spin results presented herein are believed to be the true values given by the model within the following limits:

α, deg . . . . ±1

ϕ, deg . . . . ±1

V, percent . . . . ±5

Ω, percent . . . . ±2

Turns for recovery:
When obtained from motion-picture records . . . . $\pm\frac{1}{4}$

When obtained by visual estimate . . . . $\pm\frac{1}{2}$

The preceding limits may have been exceeded for certain spins in which it was difficult to control the model in the tunnel because of the high rate of descent or because of the wandering or oscillatory nature of the spin.

Comparison between model and full-scale results in reference 3 indicated that model tests satisfactorily predicted full-scale recovery characteristics approximately 90 percent of the time and that for the remaining 10 percent of the time, the model results were of value in predicting some of the details of the full-scale spins. The airplanes generally spun at an angle of attack closer to 45° than did the corresponding models. The comparison presented in reference 3 also indicated that generally the airplane spun with the inner wing tilted more downward and with a greater altitude loss per revolution than did the corresponding models.

Because it is impracticable to ballast the model exactly and because of inadvertent damage to the model during tests, the measured weight and mass distribution of the XS2F-1 model varied from the true scaled-down values within the following limits:

Weight, percent . . . . 0 to 1 high

Center-of-gravity location, percent $\bar{c}$ . . . . 0 to 1 rearward

Moments of inertia:
I_X, percent . . . . 3 high to 13 high
I_Y, percent . . . . 3 high to 5 high
I_Z, percent . . . . 0 to 8 high

The accuracy of measuring the weight and mass distribution of the model is believed to be within the following limits:

Weight, percent	±1
Center-of-gravity location, percent $\bar{c}$	±1
Moments of inertia, percent	±5

Controls were set with an accuracy of ±1°.

TEST CONDITIONS

The mass characteristics and inertia parameters for the loadings furnished by the contractor for the XS2F-1 airplane and for the loadings tested on the model are presented in table II. Tests were performed for the model conditions listed in table III. For all tests, the landing gear and flaps were retracted. As indicated previously, in an emergency (single engine) condition the trimmer deflects simultaneously with the rudder. For this condition, the maximum deflection is 20° right and 20° left. In the normal condition the maximum deflection is as given below. For a few tests, the trimmer was fixed 10° with the spin. The model was tested with stabilizer incidence settings of 0° and -6°.

The mass-distribution parameters for the various airplane and model loadings are plotted in figure 5. As discussed in reference 4, figure 5 may be used as an aid in predicting the relative effectiveness of the controls on the recovery characteristics of the model.

The normal maximum control deflections used in the tests (measured perpendicular to the hinge line) were:

Rudder (measured with respect to trimmer), deg	30 right, 30 left
Trimmer, deg	5 right, 5 left
Elevator (measured with respect to stabilizer), deg	30 up, 15 down
Ailerons, deg	20 up, 15 down
Spoilers, deg	58 up

Upward spoiler deflection is plotted against control wheel angle in figure 6. The right spoiler is deflected above the upper surface of the wing when the wheel is rotated to the right.

RESULTS AND DISCUSSION

The results of the investigation are presented on charts 1 to 7 and on table IV. A key to the results presented on the charts is given on chart 1. The results obtained for right and left spins were generally very similar and right-spin results are arbitrarily presented. Propellers were not simulated on the model but it is felt that the results presented should be generally applicable for the airplane spinning either to the right or left with idling propellers. Because of the gyroscopic effect of twin propellers turning clockwise (as viewed from pilot's seat) the airplane right spins may, however, be slightly steeper than corresponding left spins. The model data are presented in terms of the full-scale values for the airplane at a test altitude of 30,000 feet. Based on spin-tunnel experience, it is felt that the current results are probably somewhat conservative as compared to corresponding results which would be obtained at a lower altitude.

Erect Spins

Charts 1 to 5 present erect-spin results obtained with the center of gravity at 30 percent $\bar{c}$ (most rearward) for the design flight loading. Chart 6 presents erect spin results with the center of gravity at 20 percent $\bar{c}$. Spins were generally oscillatory, primarily in pitch.

With the directional trimmer fixed 5° with the spin (chart 1) it was indicated that, in order to insure satisfactory recoveries for stabilizer settings of 0° or -6°, rudder reversal should be accompanied by movement of the elevator down. Movement of the elevator to at least two-thirds down was indicated as desirable. Lateral controls with the spin (wheel right in a right spin) had an adverse effect whereas lateral controls against the spin was favorable to recovery. The results obtained are consistent with reference 4 for the design loading which is predominantly heavy along the wings.

When the trimmer was fixed at neutral (chart 2) the results were, in general, similar to that of chart 1, although when the stabilizer was at -6° and the elevators were full up, satisfactory recoveries could be obtained by rudder reversal alone. Analysis of the results indicates, however, that full rapid rudder reversal followed approximately one-half turn later by movement of the elevators to at least two-thirds down will give the optimum recovery.

Chart 3 indicates that fixing the trimmer 5° against the spin (deflected to the left in a right spin) was favorable and that even reversal of the rudder alone would lead to satisfactory recovery characteristics for the airplane for this trimmer setting (based on the satisfactory recoveries obtained for the criterion spin).

Chart 4 presents results obtained when the trimmer was set 20° with the spin and reversed to 20° against the spin in conjunction with rudder reversal. As has been indicated previously, this movement of the controls is possible for the single-engine-operative emergency condition. Very satisfactory recoveries were obtained for this configuration by rudder and trimmer reversal.

The effect of extending the radome and magnetic airborne detector boom is shown on chart 5. These tests were made with the trimmer fixed 10° with the spin because early information available from the contractor at the time these tests were made indicated this to be the normal trimmer range. The results indicate little effect of radome and boom extension.

With the center of gravity at 20 percent $\bar{c}$ (most forward), erect spins (chart 6) appeared to be somewhat less oscillatory and a little steeper than those previously obtained. Satisfactory recovery characteristics were indicated for this loading condition by rudder reversal and elevator neutralization. No spins were indicated when the elevators were down as far as neutral.

Inverted Spins

Inverted-spin characteristics are indicated on chart 7. The order used for presenting the data for the inverted spins is different from that used for erect spins. For inverted spins, controls crossed for the established spin (right rudder pedal forward and wheel to the left for rotation to pilot's right) is presented to the right of the chart and column back is presented at the bottom. When the controls are crossed in the established spin, the lateral controls aid the rolling motion, when the controls are together, the lateral controls oppose the rolling motion. The angle ϕ and the elevator position in the chart are given as up or down relative to the ground.

The tests were made with the center of gravity at 30 percent $\bar{c}$. The results indicate that full rudder reversal should be utilized to insure recovery from any inverted spin obtained with the trimmer neutral. With the trimmer 5° against the spin (results not presented on the charts) no spin was obtained when ailerons and elevators were neutral.

Spin-Recovery Parachutes

Table IV indicates that, in an emergency, a tail parachute at least 18.75 feet in diameter (laid out flat) and having a drag coefficient of approximately 0.74 (based on laid-out-flat area) will be required to insure recovery by parachute action alone. The towline length should be approximately equal to the semispan (34.84 feet). If a parachute with a different drag coefficient is used, a corresponding adjustment will be required in parachute size. Reference 5 indicates that conventional flat-type parachutes made of low-porosity materials are unstable and may seriously affect the stability of the airplane if the parachute is opened in normal flight to test its operation. It may be desirable, therefore, to use a stable parachute (ref. 5) as an emergency spin-recovery device on the full-scale airplane.

Influence of Power

It has been indicated that asymmetric power settings may affect the spin-recovery characteristics of multiengine airplanes. The application of power as a recovery technique is discussed in reference 6, and it appears that, in general, increasing power on the inboard engine will be favorable, although increasing power on the outboard engine will be unfavorable.

Control Forces

The discussion of recovery characteristics so far has been based on control effectiveness alone without regard to the forces required to move the controls. As previously mentioned, for all tests, sufficient force was applied to the controls to move them fully and rapidly. Sufficient force must be applied to the airplane controls to move them in a similar manner in order for the model and airplane results to be comparable.

Calculations, based on the information presented in references 7 and 8, indicate that the forces required to move the rudder and elevator for recovery will probably be within the capabilities of the pilot. Reference 8 indicates that the force required to move the elevator down at spinning attitudes can be reduced by upward deflection of the elevator trim tab.

Landing Condition

The landing condition was not investigated on this model inasmuch as current Navy specifications require this airplane to be spin-demonstrated in the landing condition from only a 1-turn, or incipient spin; whereas, spin-tunnel-test data are obtained for the fully developed spin. An analysis of model tests to determine the effect of landing gear and flaps (ref. 9) indicates that, although the XS2F-1 will probably recover satisfactorily from an incipient spin in the landing condition, recoveries from fully developed spins will be unsatisfactory. If a spin is inadvertently entered in the landing condition, the flaps and landing gear should be retracted and recovery attempted immediately.

Recommended Recovery Technique

Based on the results obtained with the model, the following recovery technique is recommended for all loadings and conditions of the airplane:

For erect spins, the rudder should be reversed to full against the spin, and approximately one-half turn later the elevator should be moved to at least two-thirds down. If difficulty is encountered in recovering from spins because of inability to move the wheel sufficiently far forward, the trimmer on the vertical tail should be placed to full against the spin to insure recovery.

For recovery from inverted spins, the rudder should be reversed to full against the spin and the lateral and longitudinal controls should be neutralized.

CONCLUSIONS

Based on the results of tests of a $\frac{1}{30}$-scale model of the Grumman XS2F-1 airplane, the following conclusions regarding the spin and recovery characteristics of the airplane at an altitude of 30,000 feet are made:

1. Erect spins of the airplane in the most rearward center-of-gravity loading condition (30 percent mean aerodynamic chord) will be oscillatory, primarily in pitch. Satisfactory recoveries will be obtained by rapid full rudder reversal and movement of the elevator to at least two-thirds down. This technique applies to trimmer full with spins. Trimmer against the spin will greatly assist recovery; trimmer full against the spin will give satisfactory recoveries by full rudder reversal alone.

2. Erect spins in the most rearward center-of-gravity loading condition with the trimmer 20° with the spin will be satisfactorily terminated by simultaneous rapid full reversal of rudder and trimmer.

3. Extension of the radome and the magnetic airborne detector boom will have little effect on the spin-recovery characteristics.

4. Erect spins in the most forward center-of-gravity loading condition (20 percent mean aerodynamic chord) will be satisfactorily terminated by rapid full rudder reversal and elevator neutralization.

5. Satisfactory recoveries will be obtained from inverted spins by rapid full rudder reversal.

6. If an inadvertent spin is entered in the flap-down condition, flaps should be immediately retracted and recovery attempted.

7. An 18.75-foot diameter (laid out flat) tail parachute having a drag coefficient of 0.74 and having a towline length approximately equal to the semispan will be effective for emergency recovery from demonstration spins.

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TABLE I.- DIMENSIONAL CHARACTERISTICS OF THE GRUMMAN

XS2F-1 AIRPLANE

Over-all length, ft	42.13
Wing:	
Span, ft	69.67
Area, sq ft	485
Root chord, in.	119
Tip chord, in.	48
$\bar{c}$, in.	88.61
Leading edge $\bar{c}$, rearward leading edge root chord, in.	12.93
Aspect ratio	10
Taper ratio	0.4
Dihedral, deg	2.5
Incidence, deg	1.5
Airfoil section:	
Root	NACA $63_{(215)}$A420
Tip	NACA 63_2A415
Ailerons:	
Area, rearward of hinge line, total, sq ft	9.3
Span, percent b/2	12.9
Chord, rearward of hinge line, percent c	23
Spoilers:	
Span, percent b/2	39.2
Location, percent c	69.67
Hinge line, percent c	59.67
Slots:	
Span, percent b/2	22.2
Horizontal Tail:	
Span, ft	22.48
Area, sq ft	102.62
Stabilizer area, forward elevator hinge line, total, sq ft	76.74
Elevator area, rearward of hinge line, total, sq ft	25.88
Root chord, in.	73.2
Tip chord, in.	36.6
Aspect ratio	4.92
Nose to elevator hinge line, ft	37.55
Dihedral, deg	10
Airfoil section:	
Root	NACA 64_1A015
Tip	NACA 64_1A012

TABLE I.- DIMENSIONAL CHARACTERISTICS OF THE GRUMMAN

XS2F-1 AIRPLANE - Concluded

Vertical tail:	
Height, ft	13.08
Fin area, forward trimmer hinge line, sq ft	49.06
Trimmer area, hinge line to rudder hinge line, sq ft	23.80
Rudder area, rearward of hinge line, sq ft	19.61
Root chord, at fuselage reference line, in.	144
Tip chord, in.	62
$\bar{c}$, in.	104
Nose to trimmer hinge line at $\bar{c}$ $(0.577\bar{c})$, ft	38
Aspect ratio	1.85
Airfoil section:	
Root	NACA 64_1A015
Tip	NACA 64_1A012
Tail-damping-power factor	529×10^{-6}

TABLE II.- MASS CHARACTERISTICS AND INERTIA PARAMETERS FOR LOADINGS POSSIBLE ON THE GRUMMAN XS2F-1 AIRPLANE AND FOR LOADINGS TESTED ON THE $\frac{1}{30}$-SCALE MODEL

[Model values are given as corresponding full scale values; moments of inertia are given about the center

No.	Loading	Weight (lb)	Center-of-gravity location		Relative density μ		Moments of inertia (Slug-feet^2)			Mass param	
			$x/\bar{c}$	$z/\bar{c}$	Sea level	30,000 feet	I_X	I_Y	I_Z	$\frac{I_X - I_Y}{mb^2}$	$\frac{I_Y -}{mb^2}$
Airplane values											
1	Design flight center of gravity 30 percent $\bar{c}$ (most rearward)	22,334	0.300	-0.213	8.63	23.09	60,496	41,904	97,928	55×10^{-4}	-166 x
2	Design flight center of gravity 20$\bar{c}$ percent (most forward)	22,334	0.200	-0.207	8.63	23.09	60,494	34,339	90,365	78×10^{-4}	-167 x
Model values											
1	Design flight center of gravity 30 percent $\bar{c}$ (most rearward)	22,422	0.300	-0.171	8.67	23.20	65,878	44,178	101,656	64×10^{-4}	-170 x
2	Design flight center of gravity 20$\bar{c}$ percent (most forward)	22,539	0.206	-0.302	8.71	23.30	66,831	34,753	95,623	94×10^{-4}	-179 x

TABLE III.- CONDITIONS INVESTIGATED ON THE $\frac{1}{30}$- SCALE MODEL OF THE GRUMMAN XS2F-1 AIRPLANE

Type of spin	Loading condition	Loading No.	Stabilizer incidence	Trimmer position for steady spin	Position of radome and boom	Controls moved for recovery attempts
Erect	Center of gravity at 30 percent $\bar{c}$	1	0°	5° with	Retracted	Rudder; rudder and elevator
-do-	-do-	1	-6°	-do-	-do-	-do-
-do-	-do-	1	0°	Neutral	-do-	-do-
-do-	-do-	1	-6°	-do-	-do-	-do-
-do-	-do-	1	0°	5° against	-do-	Rudder
-do-	-do-	1	0°	20° with	-do-	Rudder and trimmer
-do-	-do-	1	-6°	-do-	-do-	-do-
-do-	-do-	1	0°	10° with	-do-	Rudder; rudder and elevator
-do-	-do-	1	0°	-do-	Extended	Rudder
-do-	Center of gravity at 20 percent $\bar{c}$	2	0°	5° with	Retracted	Rudder; rudder and elevator
Inverted	Center of gravity at 30 percent $\bar{c}$	1	0°	Neutral	-do-	Rudder
Erect	-do-	1	0°	5° with	-do-	[a]Tail parachute opening

[a]Controls maintained with the spin for the parachute recovery tests.

TABLE IV.- SPIN-RECOVERY TAIL PARACHUTE DATA OBTAINED

WITH THE $\frac{1}{30}$-SCALE MODEL OF THE GRUMMAN XS2F-1 AIRPLANE

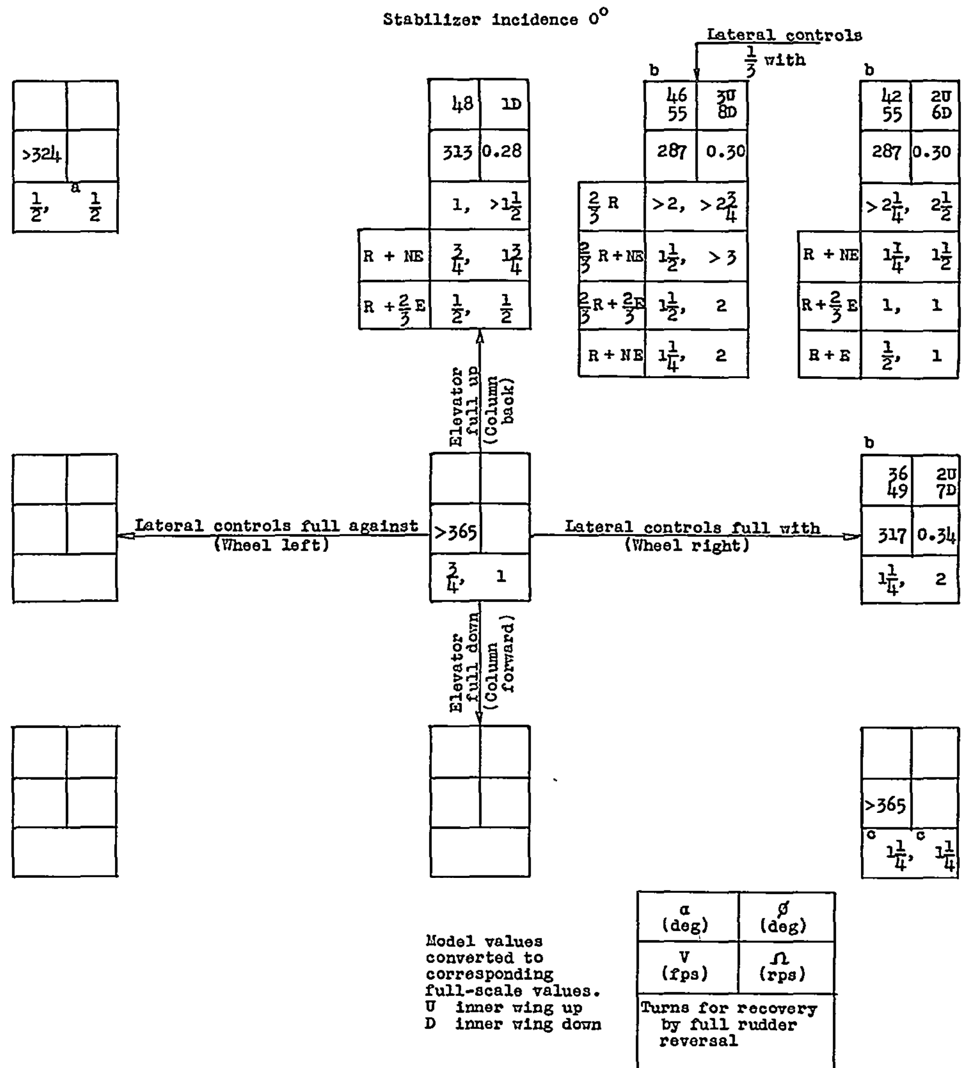
[Design-flight loading condition, center of gravity at 30 percent $\bar{c}$ (loading point 1 in table II and figure 5); recovery attempted by opening tail parachute; right erect spins; stabilizer incidence 0°; radome and boom retracted; control setting for spin - elevators full up, lateral controls $\frac{1}{3}$ with, trimmer 5° with, rudder full with spin; model values have been converted to corresponding full-scale values]

Parachute diameter (ft)	Towline length (ft)	Approximate parachute drag coefficient	Turns for recovery
10.00	34.84	0.66	>4, >5
11.25	34.84	.70	>6, $>8^{a}$
12.50	34.84	.69	>3, $>4^{a}$
13.75	34.84	.74	>4, $>6^{a}$
15.00	34.84	.71	$\frac{1}{2}$, $\frac{3}{4}$, 1, >2, >6
16.25	34.84	.69	$\frac{1}{2}$, 1, 2, >7, >8
17.50	34.84	.72	$\frac{3}{4}$, 1, >3, >5, >14
18.75	34.84	.74	$\frac{1}{2}$, $\frac{1}{2}$, $\frac{3}{4}$, 1, $1\frac{1}{4}$
20.00	34.84	.73	$\frac{1}{2}$, $\frac{1}{2}$, $\frac{1}{2}$, $\frac{1}{2}$, $\frac{3}{4}$
21.25	34.84	.81	$\frac{1}{2}$, $\frac{1}{2}$, $\frac{3}{4}$, 1, $1\frac{1}{4}$

[a]Visual estimate

CHART 1.- ERECT SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL IN THE DESIGN-FLIGHT LOADING CONDITION AND CENTER OF GRAVITY AT 30 PERCENT $\bar{c}$ WITH THE TRIMMER 5° WITH THE SPIN

[Loading point 1 in table II and figure 5; radome and boom retracted; recovery attempted by rapid full rudder reversal except as indicated (recovery attempted from, and steady-spin data presented for, rudder-full-with spins); right spins]



Other control manipulations employed for recovery attempts	
R + NE	Full rudder reversal and elevator neutralization
R + $\frac{2}{3}$ E	Full rudder reversal and elevator movement to $\frac{2}{3}$ down
R + E	Full rudder reversal and elevator movement to full down
$\frac{2}{3}$ R	Rudder reversal to $\frac{2}{3}$ against the spin
$\frac{2}{3}$ R + NE	Rudder reversal to $\frac{2}{3}$ against the spin and elevator neutralization
$\frac{2}{3}$ R + $\frac{2}{3}$ E	Rudder reversal to $\frac{2}{3}$ against the spin and elevator movement to $\frac{2}{3}$ down

[a]Visual estimate.
[b]Oscillatory spin, range of values given.
[c]Model entered an inverted spin.

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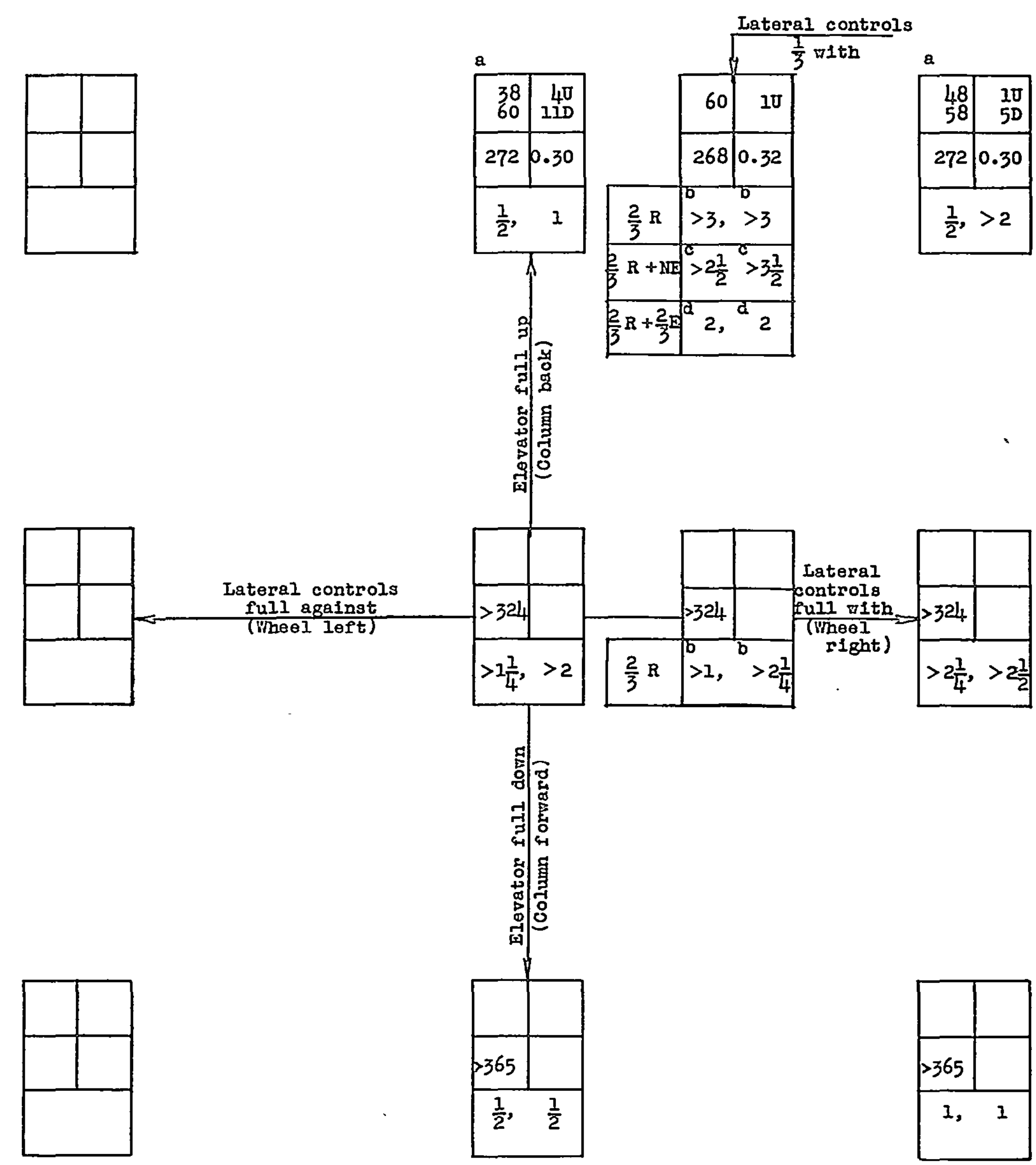
CHART 1 (CONCLUDED).- ERECT SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL IN THE DESIGN-FLIGHT LOADING CONDITION AND CENTER OF GRAVITY AT 30 PERCENT $\bar{c}$ WITH THE TRIMMER 5° WITH THE SPIN

[Loading point 1 in table II and figure 5; radome and boom retracted; recovery attempted by rapid full rudder reversal except as indicated (recovery attempted from, and steady spin data presented for, rudder-full-with spins); right spins]

Stabilizer incidence -6°



[a]Oscillatory spin, range of values given.
[b]Recovery attempted by rudder reversal from full with to $\frac{2}{3}$ against the spin.
[c]Recovery attempted by simultaneous rudder reversal from full with to $\frac{2}{3}$ against the spin and elevator neutralization.
[d]Recovery attempted by simultaneous rudder reversal from full with to $\frac{2}{3}$ against the spin and elevator movement to $\frac{2}{3}$ down.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)
V (fps)	Ω (rps)
Turns for recovery by full rudder reversal	

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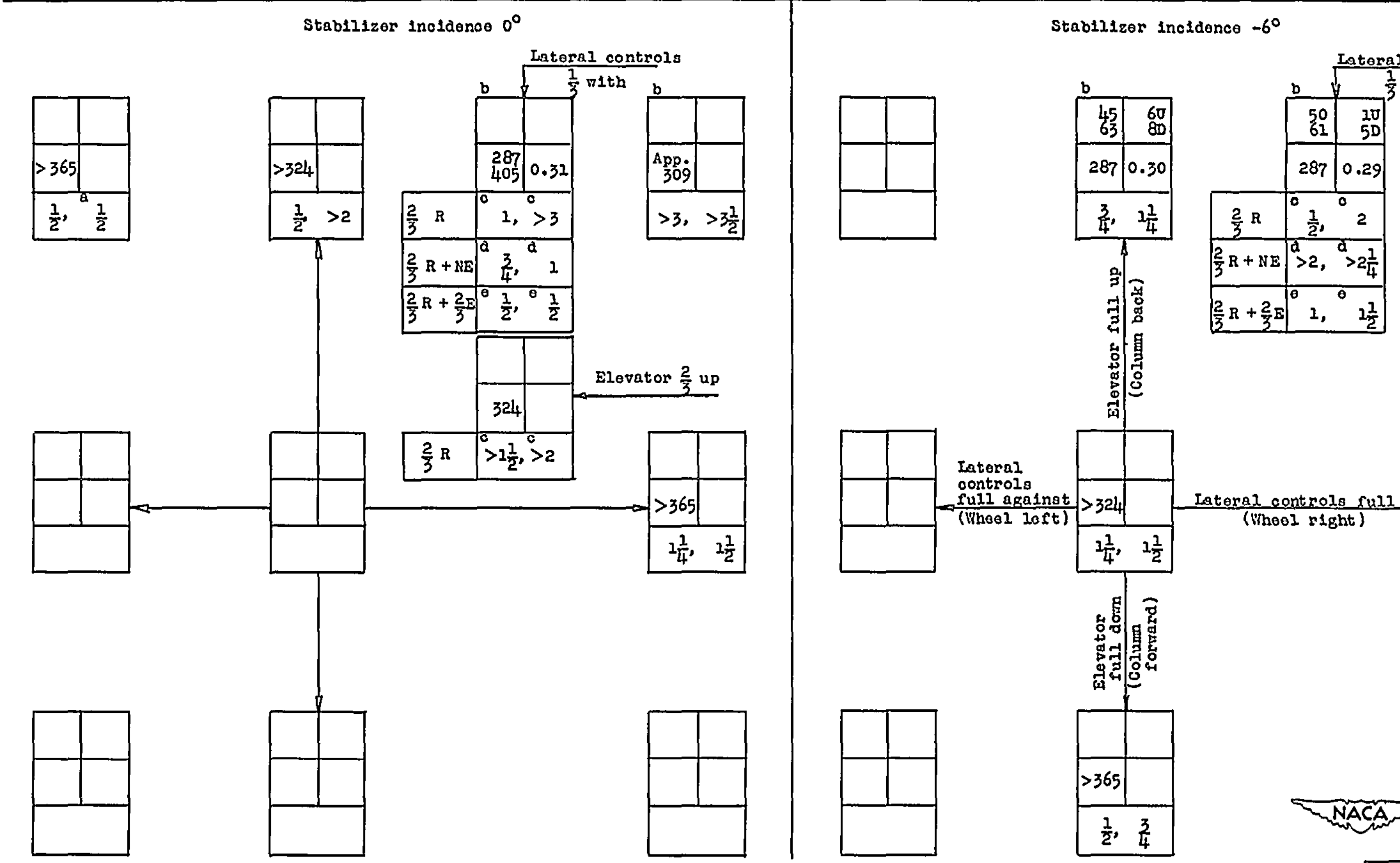
CHART 2.- ERECT SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL IN THE DESIGN-FLIGHT LOADING CONDITION AND CENTER OF GRAVITY AT 30 PERCENT $\bar{c}$ WITH THE TRIMMER NEUTRAL

[Loading point 1 in table II and figure 5; stabilizer incidence as indicated; radome and boom retracted; recovery attempted by rapid full rudder reversal except as indicated (recovery attempted from, and steady-spin data presented for, rudder-full-with spins); rig



[a]Visual estimate.

[b]Oscillatory spin, range of values given.

[c]Recovery attempted by rudder reversal from full with to $\frac{2}{3}$ against the spin

[d]Recovery attempted by simultaneous rudder reversal from full with to $\frac{2}{3}$ against the spin and elevator neutralization.

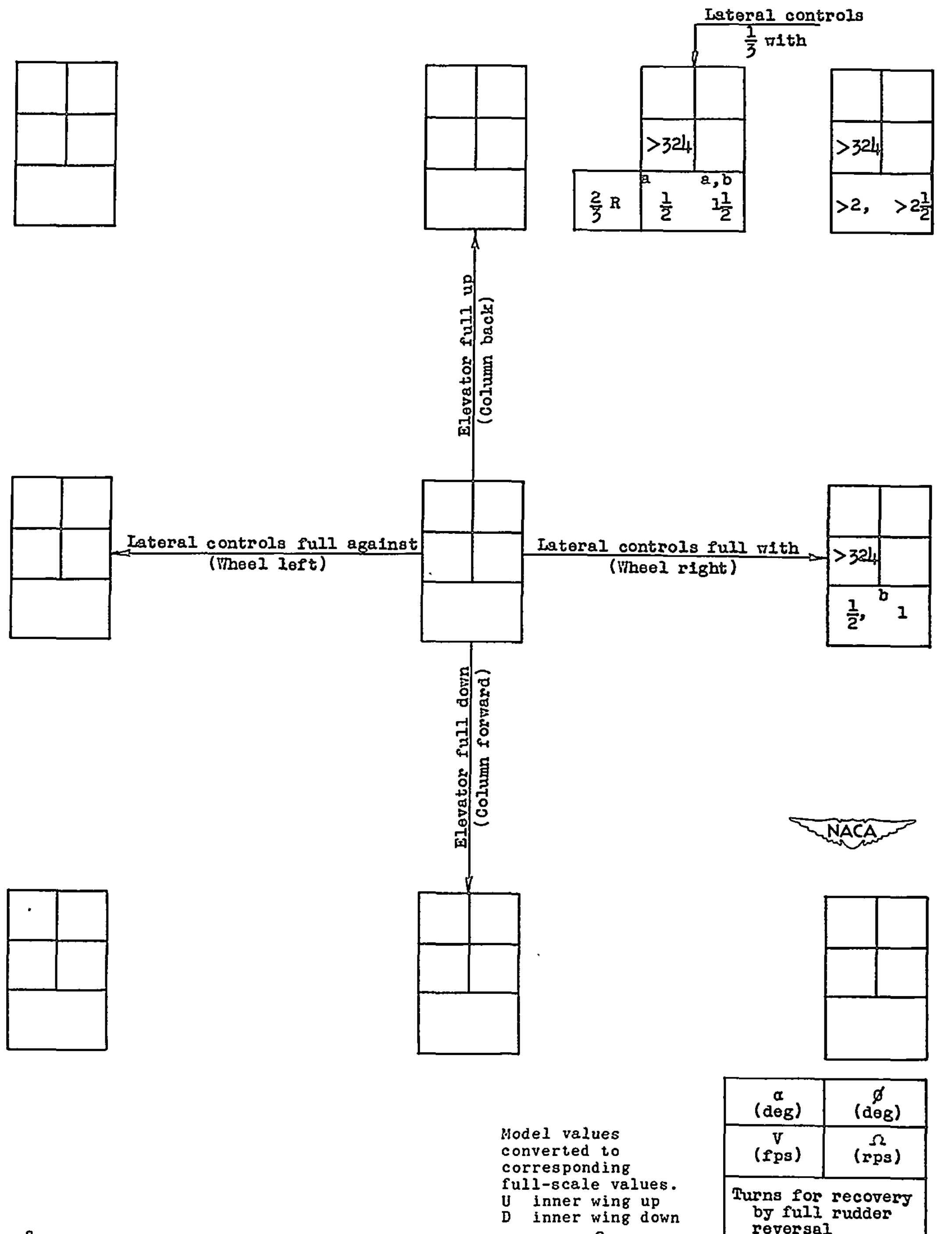
[e]Recovery attempted by simultaneous rudder reversal from full with to $\frac{2}{3}$ against the spin and elevator movement to $\frac{2}{3}$ down.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (de
V (fp
Turn by re

CHART 3.- ERECT SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL IN THE DESIGN FLIGHT LOADING CONDITION AND CENTER OF GRAVITY AT 30 PERCENT $\bar{c}$ WITH THE TRIMMER 5° AGAINST THE SPIN

[Loading point 1 in table II and figure 5; stabilizer incidence 0°; radome and boom retracted, recovery attempted by rapid full rudder reversal except as indicated (recovery attempted from, and steady-spin data presented for, rudder-full-with spins); right spins]



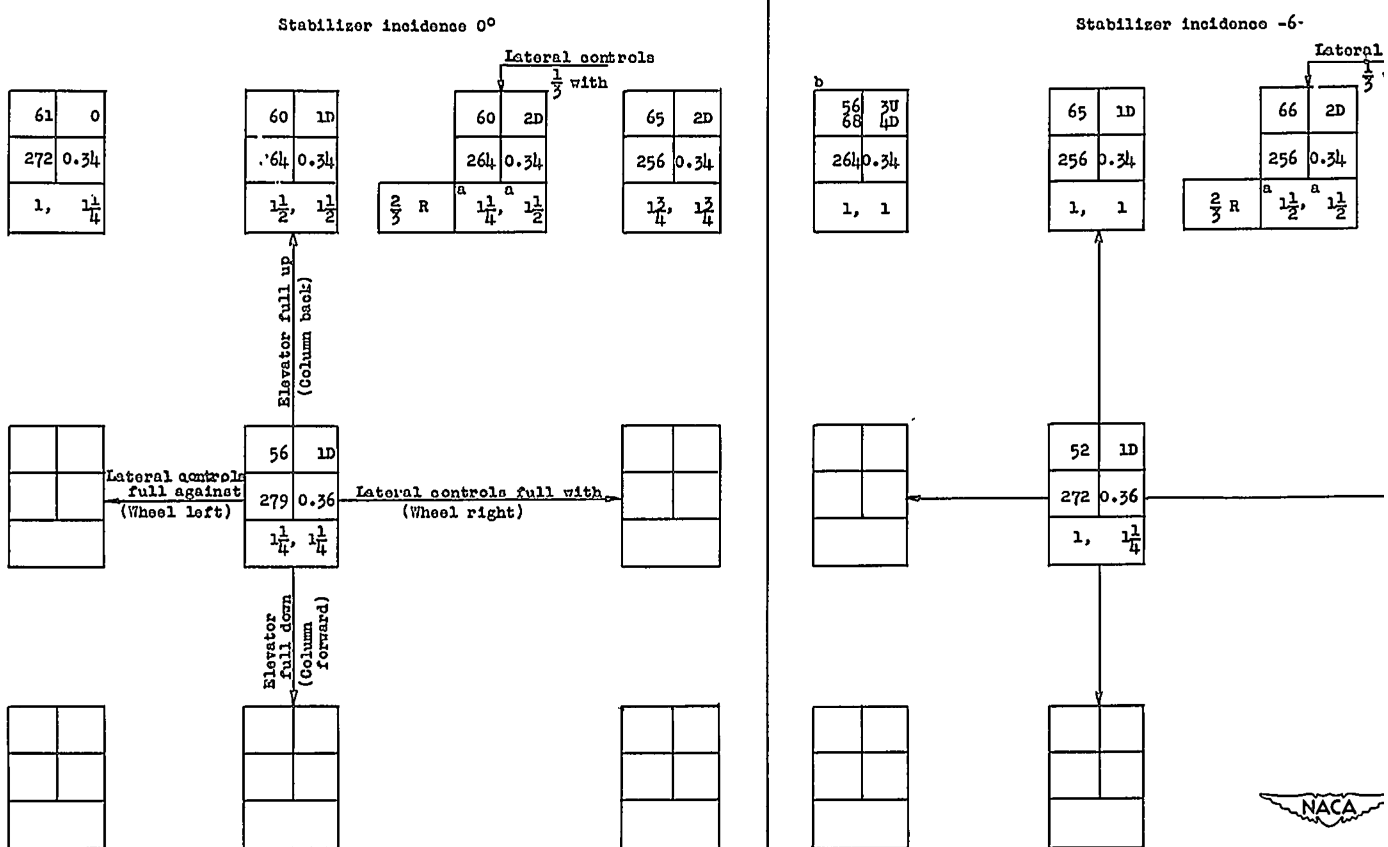
[a]Recovery attempted by rudder reversal from full with to $\frac{2}{3}$ against the spin.

[b]Visual estimate.

[redacted]

CHART 4.- ERECT SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL FOR THE SINGLE-ENGINE-OPERATIVE EMERGENCY CONDITION
(TRIMMER MOVES MAXIMUM OF 20° WITH OR AGAINST THE SPIN PROPORTIONAL TO RUDDER DEFLECTION)

[Loading point 1 in table II and figure 5; stabilizer incidence as indicated; radome and boom retracted; recovery attempted by rapid full rudder and trimmer reversal except as indicated (recovery attempted from, and steady-spin data presented for, rudder- and trimmer-full-with spins); right spins]



[a]Recovery attempted by rudder and trimmer reversal from full with to $\frac{2}{3}$ against the spin.

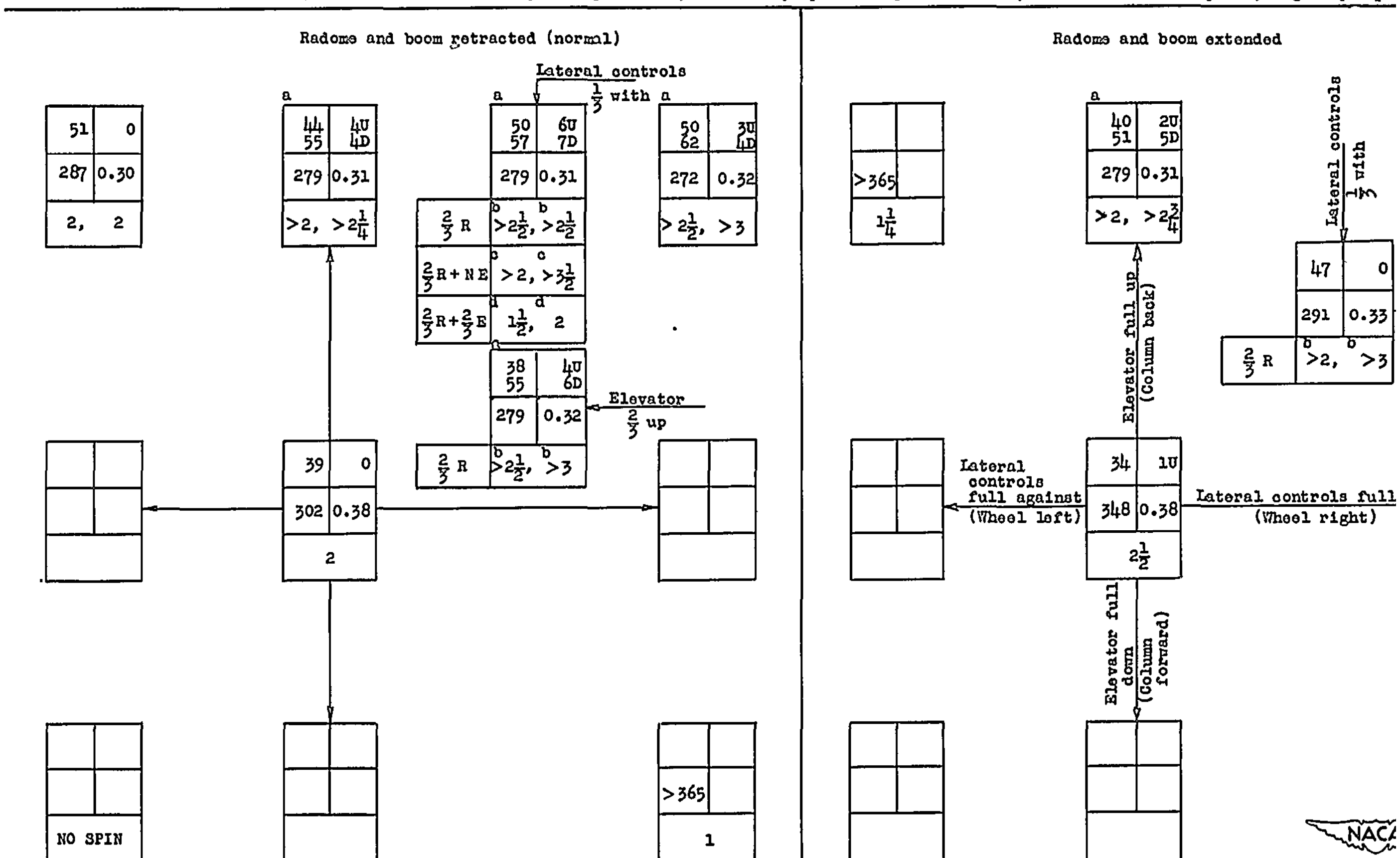
[b]Oscillatory spin, range of values given.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

(de
(fi
Turn by tri

CHART 5.- ERECT SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL IN THE DESIGN FLIGHT LOADING CONDITION AND CENTER OF GRAVITY AT 30 PERCENT $\bar{c}$ WITH THE TRIMMER 10° WITH THE SPIN

[Loading point 1 in table II and figure 5; stabilizer incidence 0°; radome and boom as indicated; recovery attempted by rapid full r[udder] reversal except as indicated (recovery attempted from, and steady-spin data presented for, rudder-full-with spins); right spins]



[a]Oscillatory spin, range of values given.

[b]Recovery attempted by rudder reversal from full with to $\frac{2}{3}$ against the spin.

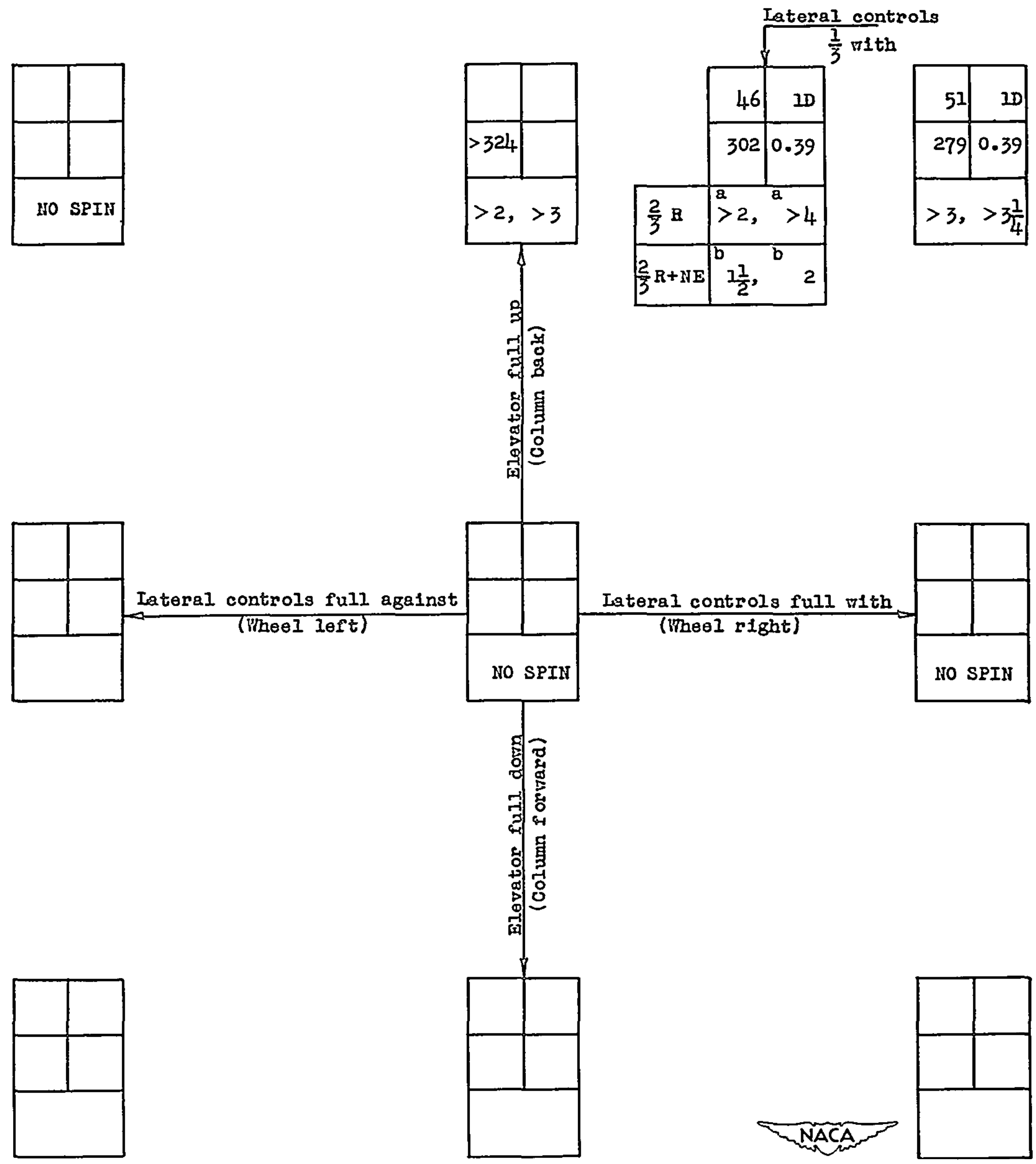
[c]Recovery attempted by simultaneous rudder reversal from full with to $\frac{2}{3}$ against the spin and elevator neutralization.

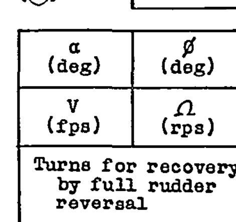
[d]Recovery attempted by simultaneous rudder reversal from full with to $\frac{2}{3}$ against the spin and elevator movement to $\frac{2}{3}$ down.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

CHART 6.- ERECT SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL IN THE DESIGN-FLIGHT LOADING CONDITION AND CENTER OF GRAVITY AT 20 PERCENT $\bar{c}$ WITH THE TRIMMER 5° WITH THE SPIN

[Loading point 2 in table II and figure 5; stabilizer incidence 0°; radome and boom retracted; recovery attempted by rapid full rudder reversal except as indicated (recovery attempted from, and steady-spin data presented for, rudder-full-with spins); right spins]





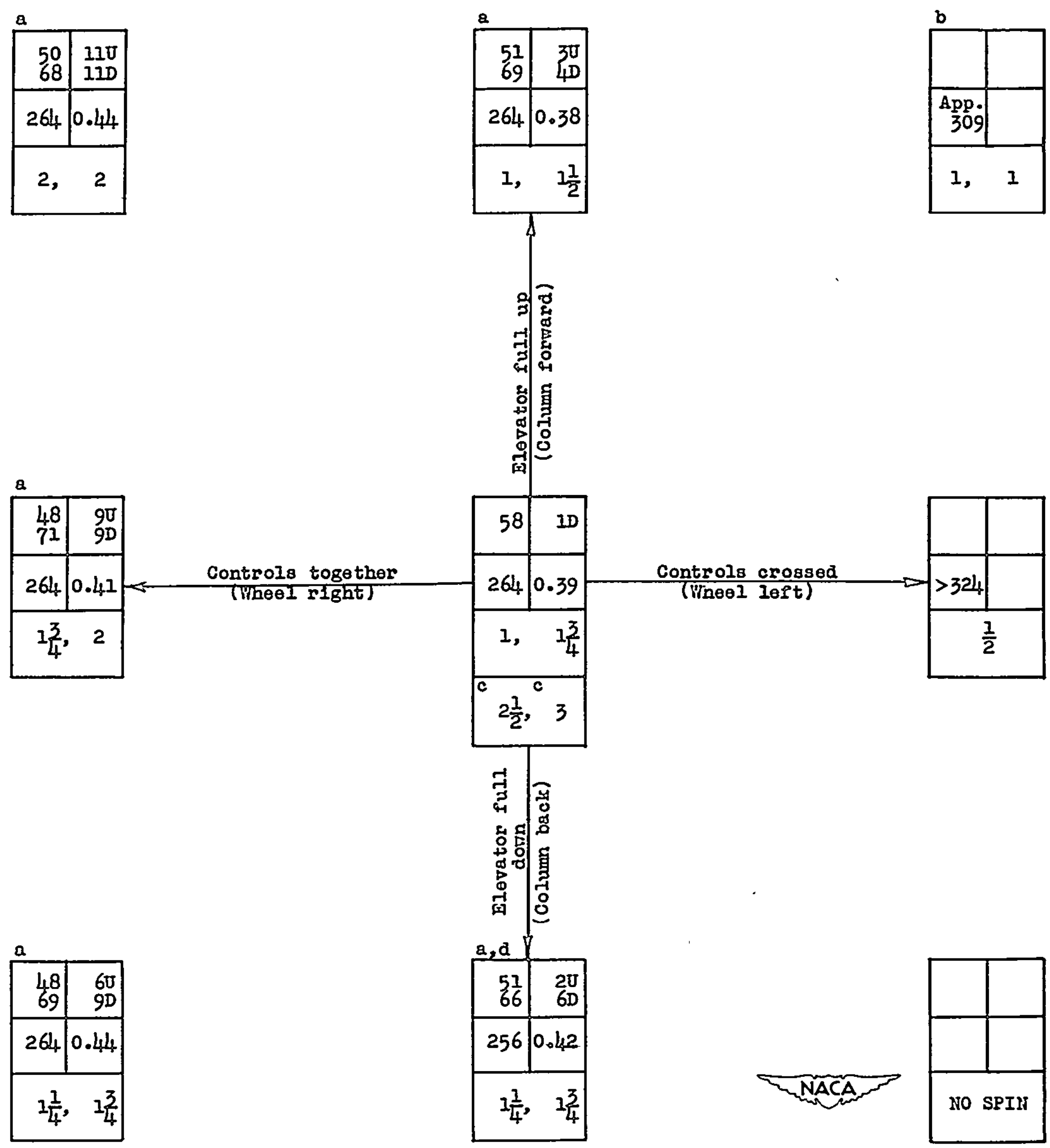
[a]Recovery attempted by rudder reversal from full with to $\frac{2}{3}$ against the spin.

[b]Recovery attempted by simultaneous rudder reversal from full with to $\frac{2}{3}$ against the spin and elevator neutralization.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

CHART 7.- INVERTED SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL IN THE DESIGN-FLIGHT LOADING CONDITION AND CENTER OF GRAVITY AT 30 PERCENT $\bar{c}$

[Loading point 1 in table II and figure 5; trimmer neutral; stabilizer incidence 0°; radome and boom retracted; recovery attempted by rapid full rudder reversal except as indicated (recovery attempted from, and steady-spin data presented for, rudder-full-with spins); spins to pilot's right]



[a]Oscillatory spin, range of values given.
[b]Wandering spin.
[c]Recovery attempted by rudder neutralization.
[d]No spin condition also obtained.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	ϕ (deg)
V (fps)	Ω (rps)
Turns for recovery by full rudder reversal	

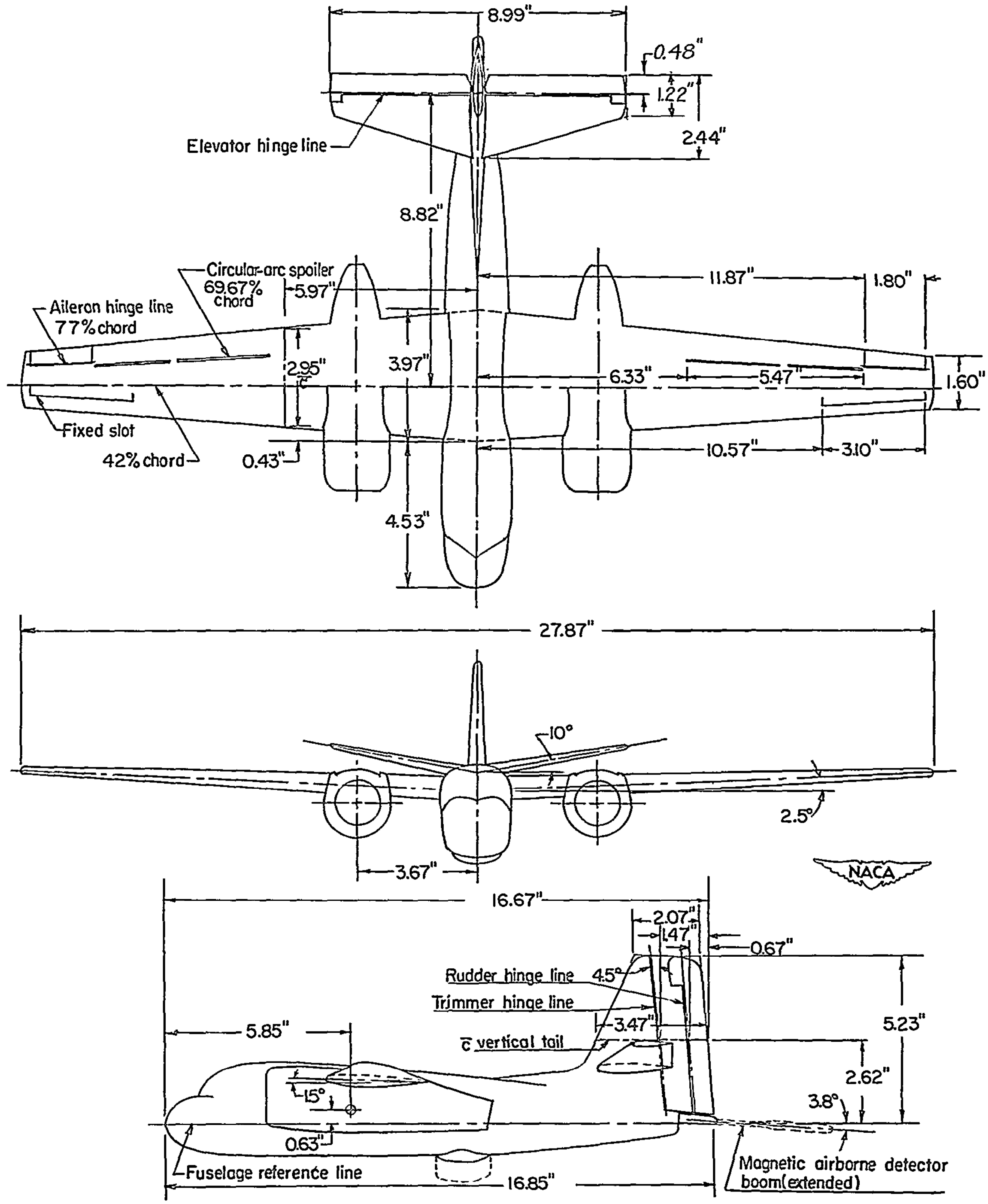


Figure 1.- Sketch of the $\frac{1}{30}$-scale model of the Grumman XS2F-1 airplane. Center of gravity shown is for design-flight most rearward position.

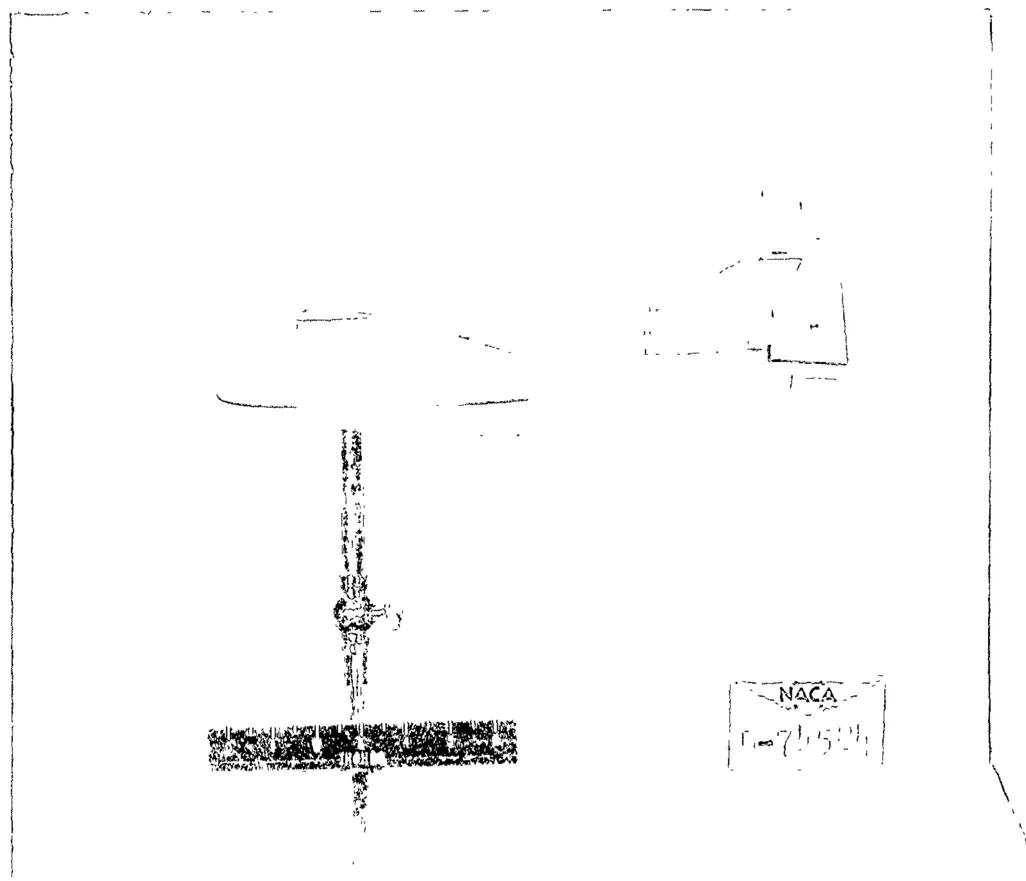


Figure 2.- Photograph of the $\frac{1}{30}$-scale model of the Grumman XS2F-1 airplane.

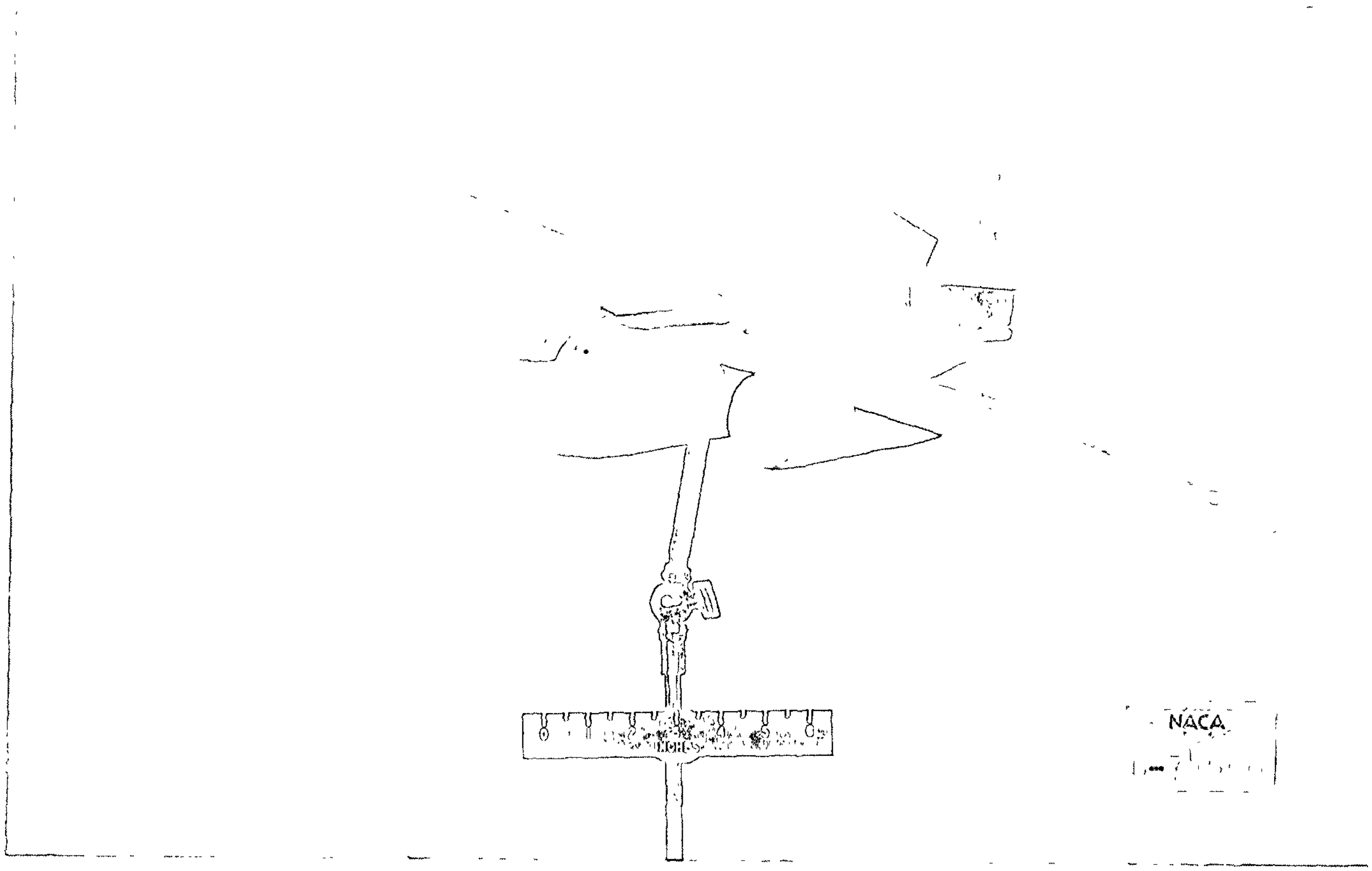


Figure 3.- Photograph of the $\frac{1}{30}$-scale model of the Grumman XS2F-1 airplane showing the circular-arc spoilers deflected.

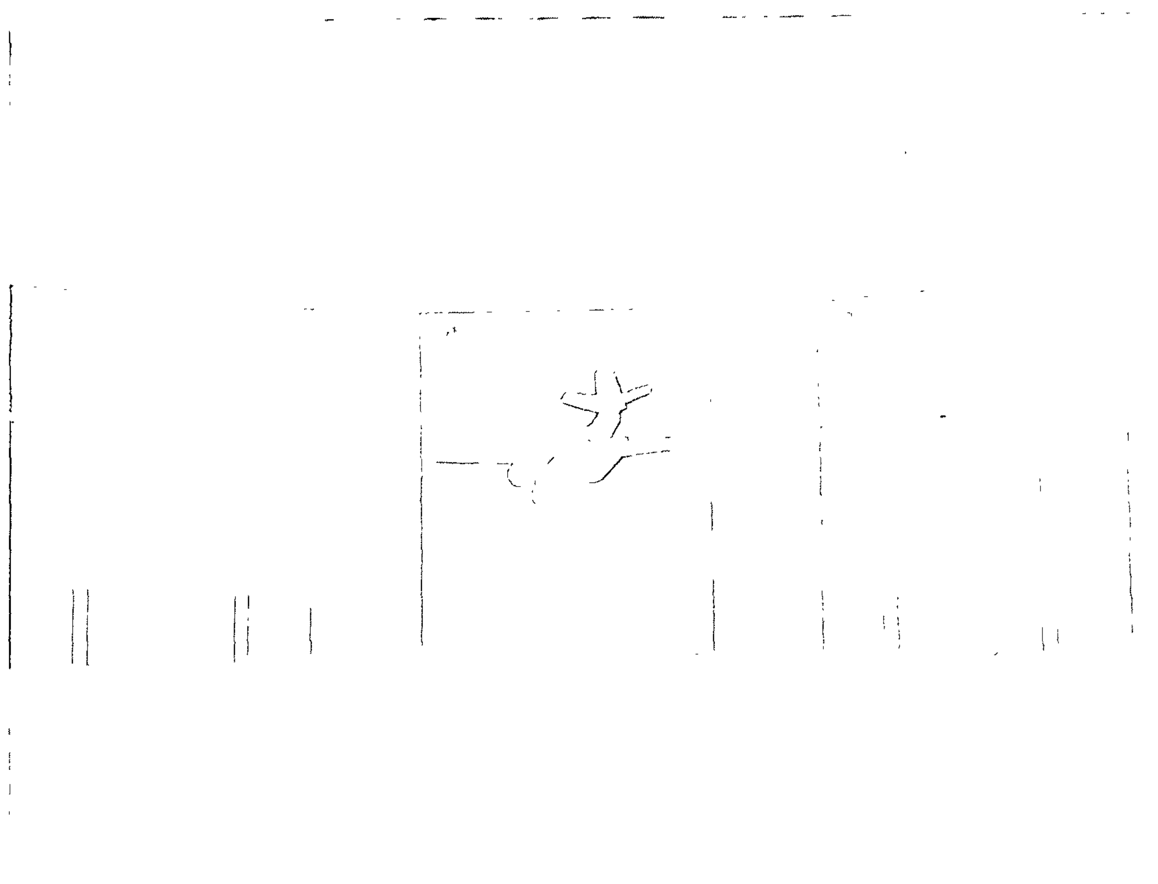


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Figure 4.- Photograph of the $\frac{1}{30}$-scale model of the Grumman XS2F-1 airplane spinning in the Langley 20-foot free-spinning tunnel.

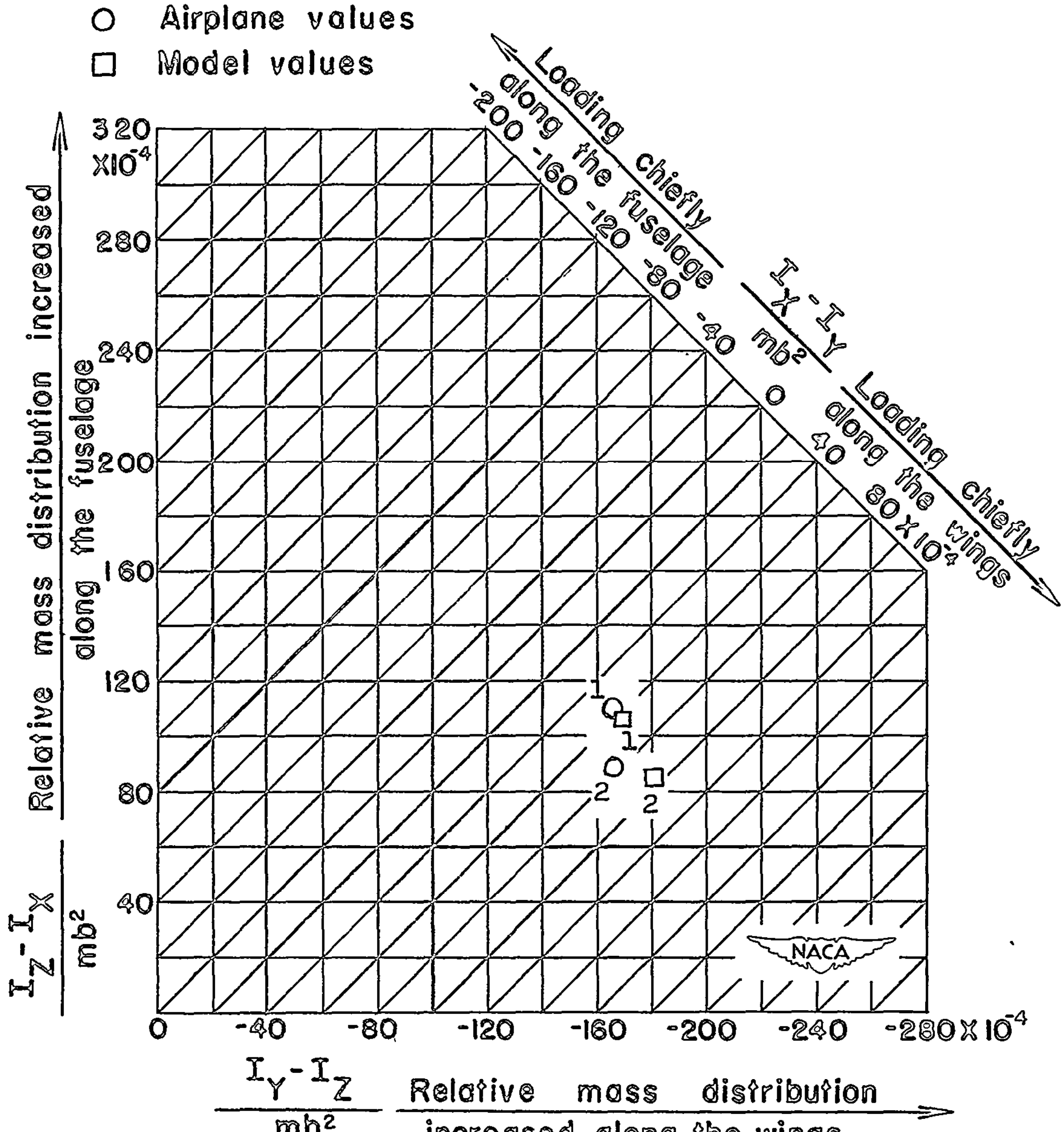

Figure 5.- Mass parameters for the loading conditions of the Grumman XS2F-1 airplane and for the loadings investigated on the model.

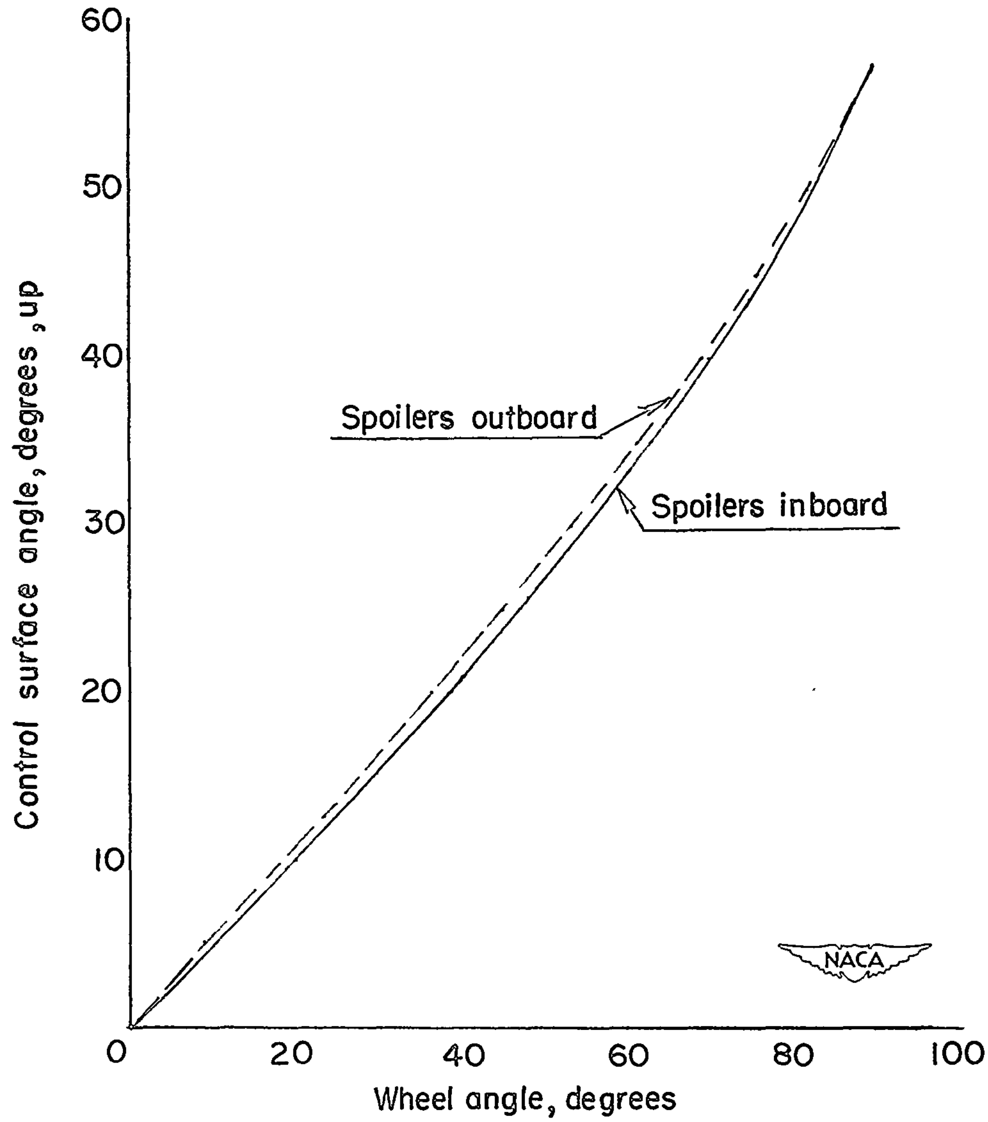

Figure 6.- Deflection of spoilers relative to control wheel position for the Grumman XS2F-1 airplane. Spoiler angle is zero when upper edge of spoiler is flush with wing top contour.

SECURITY INFORMATION

[redacted]